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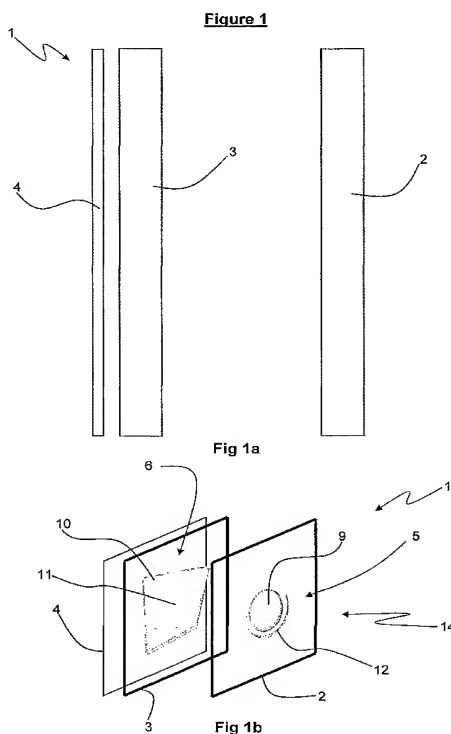
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(54) Title: IMPROVEMENTS IN MULTI-LAYERED DISPLAYS



(57) Abstract: A method, system, computer software and display for generating and displaying a target image (14) on a multi-layered display (1). The target image (14) includes a graphical object (9) displayed on a first display layer (2) of the multi-layered display (1) and contextual elements (10) displayed on a second display layer (3). The graphical object (9) is provided with a peripheral boundary region (12) composed of contextual elements (10) displayed on the second display layer (3). A projection of the peripheral boundary region (12) on the first display layer (2) demarcates a silhouette (11) on the second display layer (3).



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TITLE

Improvements in multi-layered displays

FIELD OF THE INVENTION

5 The invention relates to improvements in and relating to electronic visual displays and in particular to improved methods, systems and computer software for generating images on multi-focal plane displays.

BACKGROUND

Electronic display technology for displaying graphical images and/or text has evolved dramatically to meet the pervasive user demand for more realistic and interactive displays.
10 A wide range of display technologies with differing capabilities are now available including:

- Cathode Ray Tube (CRT)
- Bistable display
- Electronic paper
- 15 • Nixie tube displays
- Vector display
- Flat panel display
- Vacuum fluorescent display (VF)
- Light-emitting diode (LED) displays
- 20 • Electroluminescent Displays (ELD)
- Plasma display panels (PDP)
- Liquid crystal display (LCD)
 - High-Performance Addressing (HPA)
 - Thin-film transistor displays (TFT)
- 25 • Organic light-emitting diode displays (OLED)
- Surface-conduction electron-emitter display (SED) (experimental)
- Laser TV (forthcoming)
- Carbon nanotubes (experimental)
- Nanocrystal displays (experimental), using quantum dots to make vibrant, flexible
30 screens.

However, most display technologies are generally only capable of displaying two-dimensional images on a single screen. The ability to form images at different depths within a display, whether real or perceived, has been the subject of significant and

ongoing research and development in the quest to provide display technology capable of replicating or augmenting the depth effects conferred by normal human sight.

The manner in which human beings process visual information has been the subject of extensive and prolonged research in an attempt to understand this complex process.

- 5 This research has included the effects of depth or 'apparent depth' provided by volumetric, three- dimensional or multi-focal plane displays.

The term "preattentive processing" has been coined to denote the act of the subconscious mind in analysing and processing visual information which has not become the focus of the viewer's conscious awareness.

- 10 When viewing a large number of visual elements, certain variations or properties in the visual characteristics of elements can lead to rapid detection by preattentive processing. This is significantly faster than requiring a user to individually scan each element, scrutinising for the presence of the said properties. Exactly what properties lend themselves to preattentive processing has in itself been the subject of substantial
15 research. Colour, shape, three-dimensional visual clues, orientation, movement and depth have all been investigated to discern the germane visual features that trigger effective preattentive processing.

- Researchers have conducted experiments using target and boundary detection in an attempt to classify preattentive features. Preattentive target detection was tested by
20 determining whether a target element was present or absent within a field of background distractor elements. Boundary detection involves attempting to detect the boundary formed by a group of target elements with a unique visual feature set within distractors. It may be readily visualised for example that a red circle would be immediately discernible set amongst a number of blue circles.

- 25 Equally, a circle would be readily detectable if set amongst a number of square shaped distractors. In order to test for preattentiveness, the number of distractors as seen is varied and if the search time required to identify the targets remains constant, irrespective of the number of distractors, the search is said to be preattentive. Similar search time limitations are used to classify boundary detection searches as preattentive.

- 30 A widespread threshold time used to classify preattentiveness is 200-250 milliseconds as this only allows the user opportunity for a single 'look' at a scene. This timeframe is insufficient for a human to consciously decide to look at a different portion of the scene. Search tasks such as those stated above maybe accomplished in less than 200

milliseconds, thus suggesting that the information in the display is being processed in parallel unattendedly or pre-attentively.

However, if the target is composed of a conjunction of unique features, i. e. a conjoin search, then research shows that these may not be detected preattentively. Using the
5 above examples, if a target is included for example, of a red circle set within distractors including blue circles and red squares, it is not possible to detect the red circle preattentively as all the distractors include one of the two unique features of the target.

Whilst the above example is based on a relatively simple visual scene, Enns and Rensink
[1990] identified that targets given the appearance of being three dimensional objects can
10 also be detected preattentively. Thus, for example a target represented by a perspective view of a cube shaded to indicate illumination from above would be preattentively detectable amongst a plurality of distractor cubes shaded to imply illumination from a different direction. This illustrates an important principle in that the relatively complex, high-level concept of perceived three dimensionality may be processed preattentively by
15 the sub-conscious mind.

In comparison, if the constituent elements of the above described cubes are re- orientated to remove the apparent three dimensionality, subjects cannot preattentively detect targets which have been inverted for example. Additional experimentation by Brown et al [1992] confirm that it is the three dimensional orientation characteristic which is preattentively
20 detected. Nakaymyama and Silverman [1986] showed that motion and depth were preattentive characteristics and that furthermore, stereoscopic depth could be used to overcome the effects of conjoin. This reinforced the work done by Enns Rensink in suggesting that high-level information is conceptually being processed by the low-level visual system of the user. To test the effects of depth, subjects were tasked with detecting
25 targets of different binocular disparity relative to the distractors. Results showed a constant response time irrespective of the increase in distractor numbers.

These experiments were followed by conjoin tasks whereby blue distractors were placed on a front plane whilst red distractors were located on a rear plane and the target was either red on the front plane or blue on the rear plane for stereo colour (SC) conjoin tests,
30 whilst stereo and motion (SM) trials utilised distractors on the front plane moving up or on the back plane moving down with a target on either the front plane moving down or on the back plane moving up.

Results showed the response time for SC and SM trials were constant and below the 250 milliseconds threshold regardless of the number of distractors. The trials involved conjoin

as the target did not possess a feature unique to all the distractors. However, it appeared the observers were able to search each plane preattentively in turn without interference from distractors in another plane.

This research was further reinforced by Melton and Scharff [1998] in a series of experiments in which a search task consisting of locating an intermediate-sized target amongst large and small distractors tested the serial nature of the search whereby the target was embedded in the same plane as the distractors and the preattentive nature of the search whereby the target was placed in a separate depth plane to the distractors.

The relative influence of the total number of distractors present (regardless of their depth) versus the number of distractors present solely in the depth plane of the target was also investigated. The results showed a number of interesting features including the significant modification of the response time resulting from the target presence or absence. In the target absence trials, the reaction times of all the subjects displayed a direct correspondence to the number of distractors whilst the target present trials did not display any such dependency. Furthermore, it was found that the reaction times in instances where distractors were spread across multiple depths were faster than for distractors located in a single depth plane.

Consequently, the use of a plurality of depth/focal planes as a means of displaying information can enhance preattentive processing with enhanced reaction/assimilation times.

Three-dimensional or multi-focal plane displays are known to provide numerous advantages or capabilities unavailable with conventional two-dimensional displays. Examples of a three-Dimensional and multi-focal plane displays include Stereoscopic displays and Multi-Layer Displays (MLD) respectively.

Known three-dimensional displays seek to provide binocular depth cues to the viewer via a variety of techniques including separate head-mounted displays located directly in front of each eye, lenticular displays and holography. Unfortunately, each of these possesses certain limitations. Head-mounted displays add ergonomic inconvenience, reduce the viewer's peripheral awareness and are often cumbersome and can cause nausea, headaches and/or disorientation. Lenticular displays are only really effective at oblique viewing angles and holography is currently limited to displaying static images.

Stereoscopic (and auto-stereoscopic) displays provide the appearance of a 3D image by providing slightly different visual images to the left and right eyes of the viewer to utilise the binocular capabilities of the human visual system.

MLD systems are multi-focal plane displays that use multiple layered screens or 'display layers' aligned parallel with each other in a stacked arrangement with a physical separation between each screen. Each screen is capable of displaying images on a different focal plane and thus such MLD systems are often referred to as Multi-focal plane displays. Thus, multiple images separated by a physical separation or 'depth' can be displayed on one display. PCT Publication No. WO 99142889 discloses such an MLD in which depth is created by displaying images on the background screen furthest from the viewer which will appear at some depth behind images displayed on the screen(s) closer to the user. The benefits of MLDs, in particular those utilising the technology described in the published PCT Patent Publication Nos. WO 1999/042889 and WO 1999/044095 are gaining increasingly widespread recognition and acceptance due to their enhanced capabilities compared to conventional single focal plane displays (SLD).

The benefits of MLDs are especially germane to displays using liquid crystal displays (LCD), though MLDs can also be formed using other display technologies, e.g. an LCD front display layer may be layered in front of an OLED rear display layer.

There are two main types of Liquid Crystal Displays used in computer monitors, passive matrix and active matrix. Passive-matrix Liquid Crystal Displays use a simple grid to supply the charge to a particular pixel on the display. Creating the grid starts with two glass layers called substrates. One substrate is given columns and the other is given rows made from a transparent conductive material. This is usually indium tin oxide. The rows or columns are connected to integrated circuits that control when a charge is sent down a particular column or row. The liquid crystal material is sandwiched between the two glass substrates, and a polarizing film is added to the outer side of each substrate.

A pixel is defined as the smallest resolvable area of an image, either on a screen or stored in memory. Each pixel in a monochrome image has its own brightness, from 0 for black to the maximum value (e.g. 255 for an eight-bit pixel) for white. In a colour image, each pixel has its own brightness and colour, usually represented as a triple of red, green and blue intensities. To turn on a pixel, the integrated circuit sends a charge down the correct column of one substrate and a ground activated on the correct row of the other. The row and column intersect at the designated pixel and that delivers the voltage to untwist the liquid crystals at that pixel.

The passive matrix system has significant drawbacks, notably slow response time and imprecise voltage control. Response time refers to the Liquid Crystal Displays ability to refresh the image displayed. Imprecise voltage control hinders the passive matrix's ability to influence only one pixel at a time. When voltage is applied to untwist one pixel, the

pixels around it also partially untwist, which makes images appear fuzzy and lacking in contrast. Active-matrix Liquid Crystal Displays depend on thin film transistors (TFT). Thin film transistors are tiny switching transistors and capacitors. They are arranged in a matrix on a glass substrate.

- 5 To address a particular pixel, the proper row is switched on, and then a charge is sent down the correct column. Since all of the other rows that the column intersects are turned off, only the capacitor at the designated pixel receives a charge. The capacitor is able to hold the charge until the next refresh cycle. And if the amount of voltage supplied to the crystal is carefully controlled, it can be made to untwist only enough to allow some light
10 through. By doing this in very exact, very small increments, Liquid Crystal Displays can create a grey scale.

- Most displays today offer 256 levels of brightness per pixel. A Liquid Crystal Display that can show colours must have three sub-pixels with red, green and blue colour filters to create each colour pixel. Through the careful control and variation of the voltage applied,
15 the intensity of each sub-pixel can range over 256 shades. Combining the sub-pixel produces a possible palette of 16.8 million colours (256 shades of red x 256 shades of green x 256 shades of blue). Liquid Crystal Displays employ several variations of liquid crystal technology, including super twisted nematics, dual scan twisted nematics, ferroelectric liquid crystal and surface stabilized ferroelectric liquid crystal. They can be lit
20 using ambient light in which case they are termed as reflective, backlit and termed Transmissive, or a combination of backlit and reflective and called transfective.

There are also emissive technologies such as Organic Light Emitting Diodes (OLED), and other similar technologies which project an image directly onto the back of the retina which are addressed in the same manner as Liquid Crystal Displays.

- 25 To aid clarity and avoid prolixity, reference herein will be made to an "MLD" with two display layers, i.e. an MLD having front and rear display layers. However, this should not be seen to be limiting as the MLD may include three or more display layers as required by the application.

- In general an MLD is used to simultaneously display images on the front and rear display
30 layers. The MLD is configured to display output image data from a computer system, video/image feed or other image generator and in most applications the images are composite images formed from multiple image components, e.g. a foreground object and a background scene or a computer mouse cursor and computer software Graphical User

Interface GUI. The image components may be displayed on the same display layer or spread between both display layers.

For ease of reference, the position of the image components or 'graphical objects' on each display layer can be given as a range of orthogonal x and y co-ordinates representative of the spatial position of the image component in the plane of a display layer relative to a common fixed reference point, e.g. the edge of a display layer, viewer's position or a fixed external focal point.

Where two images are simultaneously displayed at the same x and y co-ordinates on the different display layers, the images will overlap. The image on the front display layer may thus appear to be at least partially transparent, as the image on the rear display layer may be visible through the front image component. The overlapping images can thus interfere and often the front image will appear unclear or 'ghostly'.

This problem has been addressed previously in the prior art by generating a 'shadow' or 'silhouette' of the front image component and displaying on the rear display layer behind the front image component. The silhouette is a representative image having the same general outline as the original front image and is typically 'white' i.e. the silhouette region of the rear display is made substantially transparent. Displaying the silhouette behind the front image component removes any interference from overlapped rear image components and thereby increases the clarity and perceived opacity of the front image component. An example of this 'white shadow' technique is described in WO2007/040413 which is herein incorporated by reference.

A similar technique may be used to increase the visibility of an image component appearing on a rear display layer whereby a silhouette of the rear image component is displayed on the front display layer overlapping the rear image component, thereby removing any overlapping interfering front image components minimising any interference with the rear image component.

In most MLDs the display layers are spaced apart, for example by about 7mm in the MLD described in WO99/142889. This physical separation provides the visual depth observed when using these displays. However, when using the aforementioned silhouetting method on such an MLD, a viewer viewing the display from an off-centre position will be able to identify the edges of the silhouette on the rear display layer behind the origin image component due to parallax, thereby reducing the beneficial effect provided by the silhouette.

It would thus be advantageous to provide a method of silhouetting an origin image component in a volumetric display such as an MLD to reduce interference between overlapping image components while reducing the visibility of the perceived visibility of the silhouette.

- 5 It is an object of the present invention to address the foregoing problems or at least to provide the public with a useful choice.

All references, including any patents or patent applications cited in this specification are hereby incorporated by reference. No admission is made that any reference constitutes prior art. The discussion of the references states what their authors assert, and the
10 applicants reserve the right to challenge the accuracy and pertinency of the cited documents. It will be clearly understood that, although a number of prior art publications are referred to herein, this reference does not constitute an admission that any of these documents form part of the common general knowledge in the art, in New Zealand or in any other country.

- 15 It is acknowledged that the term 'comprise' may, under varying jurisdictions, be attributed with either an exclusive or inclusive meaning. For the purpose of this specification, and unless otherwise noted, the term 'comprise' shall have an inclusive meaning – i.e. that it will be taken to mean an inclusion of not only the listed components it directly references, but also other non-specified components or elements. This rationale will also be used
20 when the term 'comprised' or 'comprising' is used in relation to one or more steps in a method or process.

DISCLOSURE OF INVENTION

The following terminology will be used throughout the specification and the intended meaning of each term is described below.

- 25 It will be appreciated that as used herein, the term:
- "image" refers to any visible effect, including a graphical image, still images, video, frames of a video or other moving imagery, frame-less moving imagery, graphical objects, text, pattern, symbol, design, shadow or other visible effect;
 - "graphical object" refers to any part or portion of an image and may include
30 multiple distinct images or image parts, contiguous portions of the same image, non-contiguous portions of the same image.

- “contextual elements” refers to any image, or graphical object displayed on a background display layer, or second display layer, or portion of same. The contextual elements attributes may include pattern, colour, shading, contrast, intensity, hue and the like. Contextual elements may be displayed uniformly across a display layer or vary in different display layer locations and/or be absent altogether.
- “image data” refers to any information or data specifying an aspect, facet or parameter of an image or part thereof, e.g. position, size, shape, orientation, colour, contrast, brightness, intensity, hue, position, shading, depth, or any other aspect, facet or parameter;
- “display” refers to any display system including one or more electronic display layers capable of generating a visible image and may include, by way of example, one or more display layers formed from a: Cathode Ray Tube (CRT), Liquid Crystal Display (LCD), Organic Light Emitting Diode (OLED), Light Emitting Diode (LED), Plasma display panels (PDP), Surface-conduction electron-emitter display (SED), Laser TV, or any other known or future display technology;
- “spatial relationship” refers to the spatial relationship between two images or parts of an image with respect to their displayed position.

It should be noted that reference herein to the singular also includes the plural and vice versa.

For ease of reference, computer program (hereinafter software) algorithms, procedures, functions, engines and other software components are described individually with respect to their intended function. However, it should be appreciated that these software components may also be combined, operated independently, interlinked, integrated or otherwise manipulated without departing from the spirit or scope of the present invention.

Reference herein to an MLD having two display layers should not be seen to be limiting as the principles of the present invention may be easily extrapolated for display on an MLD with three or more display layers.

According to one aspect of the present invention there is provided a computer-implemented method of generating images on a multi-layered display (MLD), the MLD including:

- a first display layer including a first plurality of pixels, the first display layer operable to display a first image using at least some of said pixels;
- a second display layer including a second plurality of pixels, the second display layer operable to display a second image using at least some of said second plurality of pixels, wherein one said display layer overlaps the other said display layer;

wherein said computer-implemented method includes execution of an *image generation algorithm* embodied in computer readable instructions stored in a computer-readable medium, said *image generation algorithm* executable to:

- display a target image on a MLD display, said target image including:
 - a graphical object displayed on the first display layer, and
 - contextual elements displayed on the second display layer,

wherein a projection of the graphical object on the first display layer demarcates a silhouette on the second layer.

Preferably, the target image is formed from an origin image having a graphical object and contextual elements.

Preferably, said silhouette is composed of said origin image graphical object.

Preferably, at least a portion of said silhouette is displayed with an RGB value proportional to the square root of the RGB value of a corresponding portion of said origin image graphical object and more preferably, at least a portion of said silhouette is displayed with an RGB value equal to the square root of the RGB value of the corresponding portion of said origin image graphical object.

Preferably, the RGB value of at least a portion of the graphical object displayed in the target image is proportional to the RGB value of the corresponding origin image graphical object divided by the RGB value of a corresponding portion of the silhouette.

Preferably, at least a portion of said silhouette is displayed with an alpha value proportional to the square root of the alpha value of a corresponding portion of said origin image graphical object and more preferably, at least a portion of said silhouette is displayed with an alpha value equal to the square root of the alpha value of the corresponding portion of said origin image graphical object.

Preferably, the alpha value of at least a portion of the graphical object displayed in the target image is proportional to the alpha value of the corresponding origin image graphical object divided by the alpha value of a corresponding portion of the silhouette.

Each pixel in an LCD screen stores RGB values for colour and an additional value
5 between 0 and 1, i.e. the alpha value. The alpha value determines how comparatively opaque or transparent an image element is in relation to other image elements that are displayed over the same pixels. For example, 40% alpha value for an image element will mean that it is 60% transparent (or 40% opaque).

It will be appreciated that if the silhouette is displayed with the same 'alpha' value (i.e.
10 transparency/opacity value) of the origin image graphical object the target image will appear with an alpha value equal to the silhouette alpha value multiplied by the graphical object alpha value, i.e. with an alpha value squared. The silhouette is thus preferably displayed with an alpha value equal to the square root of the origin image graphical object alpha value and the alpha value of the target image graphical object is divided by the
15 resultant silhouette alpha value to compensate.

Preferably, said silhouette is composed of a blurred copy of said origin image graphical object.

The graphical object may thus be displayed on one display layer overlapping/overlapped
20 by a silhouette (e.g. a copy of the graphical object) on the other display layer. The contextual elements will thus not be visible through the graphical object. Also, as the silhouette is a copy of the graphical object, an observer viewing the graphical object off-centre will therefore not be able to discern the silhouette. A composite target image may be formed that enhances the visibility of the graphical object with respect to the contextual elements.

25 It will be appreciated that the present invention may also be embodied in a computer system, multi-layered display or image generation algorithm configured to perform these methods.

According to one aspect of the present invention there is provided a computer-implemented method of generating images on a multi-layered display (MLD), the MLD
30 including:

- a first display layer including a first plurality of pixels, the first display layer operable to display a first image using at least some of said pixels;

- a second display layer including a second plurality of pixels, the second display layer operable to display a second image using at least some of said second plurality of pixels, wherein one said display layer overlaps the other said display layer;

5 wherein said computer-implemented method includes execution of an *image generation algorithm* embodied in computer readable instructions stored in a computer-readable medium, said *image generation algorithm* executable to:

- display a target image on a MLD display, said target image including:
 - a graphical object displayed on the first display layer, and
 - 10 • contextual elements displayed on the second display layer,

wherein said graphical object is provided with a peripheral boundary region composed of contextual elements displayed on the second display layer.

According to one aspect of the present invention there is provided a computer system configured to generate images for display on a multi-layered display (MLD), the MLD
15 including:

- a first display layer including a first plurality of pixels, the first display layer operable to display a first image using at least some of said pixels;
- a second display layer including a second plurality of pixels, the second display layer operable to display a second image using at least some of said second
20 plurality of pixels, wherein one said display layer overlaps the other said display layer;

wherein said computer system includes a system memory coupled by a bus to a processor, and wherein the system memory stores executable computer readable instructions embodying an *image generation algorithm* executable to generate target
25 image data for display as a target image on a MLD display, said target image data including:

- first image data including data for display of a first image including a graphical object displayed on the first display layer, and
- second image data including data for display of a second image
30 including contextual elements displayed on the second display layer,

wherein said first image data includes data for display of a peripheral boundary region of said graphical object composed of contextual elements displayed on the second display layer.

According to one aspect of the present invention there is provided an *image generation algorithm* embodied in computer readable instructions and executable by a computer system to generate target image data corresponding to a target image for display on a multi-layered display (MLD), the MLD including:

- a first display layer including a first plurality of pixels, the first display layer operable to display a first image using at least some of said pixels;
- a second display layer including a second plurality of pixels, the second display layer operable to display a second image using at least some of said second plurality of pixels, wherein one said display layer overlaps the other said display layer;

wherein said *image generation algorithm* is executable to generate target image data for display as a target image on a MLD display, said target image data including:

- first image data including data for display of a first image including a graphical object displayed on the first display layer, and
- second image data including data for display of a second image including contextual elements displayed on the second display layer,

wherein said first image data includes data for display of a peripheral boundary region of said graphical object composed of contextual elements displayed on the second display layer.

According to a further aspect, said *image generation algorithm* is executable to generate said target image data by processing origin image data corresponding to an origin image having a said graphical object and contextual elements.

In a further embodiment, said origin image data is processed to extract graphical object image data and contextual element image data respectively corresponding to said graphical object and said contextual elements.

According to one aspect, the second display layer may be provided with contextual elements with a substantially uniform appearance across substantially the whole second display layer. In such embodiments, the contextual elements used to provide said

peripheral boundary region of the graphical object need not be matched to a specific location of the second display layer.

In alternative embodiments, the second display layer may display a variety of differing images and contextual elements. Consequently, in order for the peripheral boundary region of a graphical object on the first display layer to merge unobtrusively with the second display layer, the contextual elements on both display layers need to be matched. Consequently, in an alternative embodiment, said peripheral boundary region contextual elements correspond to those contextual elements on the second display layer overlapped by and/or adjacent to the graphical object on the first display layer.

- 10 Preferably, the graphical object on the first display layer demarcates a silhouette on the second layer.

Preferably, said silhouette bounds a region of the second display layer without any contextual elements.

- 15 Preferably, the second display layer region bounded by said silhouette displays a pattern, texture, intensity, colour or hue which is not visible or discernable through the graphical object on the first display layer.

Preferably, said silhouette region is 'white', i.e. the silhouette region of the second display layer is made substantially transparent with the white light from a backlight being transmitted therethrough.

- 20 Preferably, said silhouette peripheral boundaries are coterminous with, or located within the overlapping boundaries of the graphical object on the first display layer.

Preferably said silhouette peripheral boundaries are concentric with the overlapping boundaries of the graphical object on the first display layer.

According to a further aspect, said *image generation algorithm* is executable to:

- 25 a) retrieve target image data relating to said target image;
b) process said target image data to:
- generate graphical object data and contextual element image data respectively corresponding to said graphical object and said contextual elements for respective display on the first and second display layers;
 - 30 • process said graphical object image data and generate silhouette data corresponding to said silhouette;

- process said contextual element image data to generate boundary region data corresponding to said boundary region.

In a further embodiment said first and second images are respectively displayed on said first and second display layers, the first image overlapping the second image or vice versa
5 and:

- said second image includes the silhouette and said contextual elements,
- said first image includes the graphical object and said boundary region.

According to a yet further embodiment, the peripheral boundary region of the graphical object and/or the silhouette peripheral boundary are manipulated to visually de-emphasize
10 said boundaries.

Preferably, said manipulation includes one or more of: feathering, blending, defocusing, dithering, graduating, grading, sequencing, serializing, tapering the pattern, texture, intensity, colour, contrast, alpha values, RGB values, saturation, brightness, or hue of said boundaries.

15 The manipulation of the peripheral boundaries of both the graphical objects and/or the silhouette attenuates the observer's awareness of the depth separation between the boundaries and instead presents the appearance of an uninterrupted continuum.

It will be readily understood that the present invention resides not only in the method of displaying images but also in the displayed image itself.

20 Thus, according to a further aspect, the present invention provides images displayed on a MLD produced by the method substantially as hereinbefore described.

Further aspects and advantages of the present invention will become apparent from the ensuing description which is given by way of example only.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings and in which like reference numerals refer to similar elements.

- 5 Figure 1a shows a schematic exploded cross-sectional view of a multi-layered display (MLD) in accordance with one preferred embodiment of the present invention;
- Figure 1b shows a schematic exploded perspective view of the MLD of figure 1 with a target image displayed thereon;
- 10 Figure 2 shows a schematic diagram of an exemplary general purpose computer system platform upon which embodiments of the present invention may be implemented;
- Figure 3 shows an example of a target image including a graphical object and contextual elements;
- 15 Figure 4 shows the target image of figure 3 with the graphical object and contextual elements displayed on front and rear screens of a multi-layered display according to one preferred embodiment;
- Figure 5 shows a silhouette of the graphical object of figures 3 and 4 displayed on the rear screen of the multi-layered display;
- 20 Figure 6 shows a boundary region of the graphical object of figures 3-5 displayed on the front screen of the multi-layered display;
- Figure 7 shows the boundary region of figure 6 in a blurred state;
- Figure 8 shows the target image displayed as first and second images according to one aspect of the present invention;
- 25 Figure 9 shows a method according to one embodiment of the present invention;
- Figure 10 shows a method according to another embodiment of the present invention;

DETAILED DESCRIPTION

Reference will now be made in detail to embodiments of the present invention, examples of which are illustrated in the accompanying drawings. While the present invention will be discussed in conjunction with the following embodiments, it will be understood that they are not intended to limit the present invention to these embodiments alone. On the contrary, the present invention is intended to cover alternatives, modifications, and equivalents which may be included within the spirit and scope of the present invention as defined by the appended claims. Furthermore, in the following detailed description of the present invention, numerous specific details are set forth in order to provide a thorough understanding of the present invention. However, embodiments of the present invention may be practiced without these specific details. In other instances, well-known methods, procedures, components, and circuits have not been described in detail so as not to unnecessarily obscure aspects of the present invention.

Some regions of the detailed descriptions which follow are presented in terms of procedures, logic blocks, processing and other symbolic representations of operations on data bits within a computer memory. These descriptions and representations are the means used by those skilled in the data processing arts to most effectively convey the substance of their work to others skilled in the art. In the present application, a procedure, logic block, process, function, or the like, is conceived to be a self-consistent sequence of steps or instructions leading to a desired result. Reference herein will also be made to various "algorithms" which should be understood to refer to one or more computer-implemented processes, procedures, functions, calculations capable of accessing, reading, processing, modifying, creating or otherwise manipulating data.

The steps are those requiring physical manipulations of physical quantities. Usually, although not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated in a computer system.

It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise as apparent from the following discussions, it is appreciated that throughout the present invention, discussions utilizing the terms such as "aborting," "accepting," "accessing," "adding," "adjusting," "analyzing," "applying," "assembling," "assigning," "balancing," "blocking," "calculating," "capturing," "combining," "comparing," "collecting," "creating," "debugging," "defining," "delivering," "depicting," "detecting," "determining," "displaying," "establishing,"

"executing," "filtering," "flipping," "generating," "grouping," "hiding," "identifying,"
 "initiating," "interacting," "modifying," "monitoring," "moving," "outputting," "performing,"
 "placing," "positioning," "presenting," "processing," "programming," "querying," "removing,"
 "repeating," "resuming," "sampling," "selecting," "simulating," "sorting," "storing,"

5 "subtracting," "suspending," "tracking," "transcoding," "transforming," "transferring,"
 "transforming," "unblocking," "using," or the like, refer to the action and processes of a
 computer system, or similar electronic computing device, that manipulates and transforms
 data represented as physical (electronic) quantities within the computer system's registers
 and memories into other data similarly represented as physical quantities within the
 10 computer system memories or registers or other such information storage, transmission or
 display devices.

Volumetric displays or multi-layered displays include two or more display layers arranged
 in a stacked, spaced apart arrangement. Given this arrangement there will be a foremost
 and a rearmost display as a minimum. In addition, there may be additional display layers
 15 located intermediate the foremost and rearmost display. Suitable volumetric displays are
 described in US patent no. 6,906,792 and include by way of example the Multi-Layer
 Displays™ licensed by PureDepth, Inc.

The display layers can be formed from various substrates, including, by way of example,
 LCD, OLED, TOLED, plasma etc. Notwithstanding that at least part of the foremost
 20 display layer is capable of being made substantially transparent such that an overlapped
 display are visible through the foremost layer. Liquid crystal displays have been most
 commonly used to form the display layers to date. Such multi-layered displays allow the
 display of discrete information on foremost and rearmost screens.

One embodiment of a multi-layered display is shown in figure 1 and is composed of first
 25 and second display layers provided in the form of front (2) and rear (3) LCD screens. The
 front (2) and rear (3) screens are positioned, parallel to, but spaced apart from each other
 with the front screen (2) overlapping the rear screen(3). A backlight array (4) is provided
 behind the rear screen (3) for providing the necessary light to the LCD screens (2, 3). As
 will be appreciated by one skilled in the art, each LCD screen (2, 3) includes a respective
 30 plurality of pixels capable of forming respective first (5) and second (6) images. The first
 screen (2) is operable to display the first image (5) using at least some of its pixels and
 the second screen (3) is operable to display a second image (6) using some of its pixels.
 The first screen (2) overlaps the second screen (3) and thus can be considered a 'front'
 screen with the second screen being a 'rear' screen.

A pixel is defined as the smallest resolvable area of an image, either on a screen or stored in memory. Each pixel in a monochrome image has its own brightness, from 0 for black to the maximum value (e. g. 255 for an eight-bit pixel) for white. In a colour image, each pixel has its own brightness and colour, usually represented as a combination of red, green and blue intensities.

It should be apparent to one skilled in the art that a number of alternative display technologies may be utilised in place of the LCD screens (2, 3). Furthermore, although figure 1 shows a single screen (1) in front of the rear screen (3) for the sake of clarity and convenience, any number of additional (at least partially transparent) display layers may be incorporated. Such displays provide a three dimensional quality to the scene viewed by an observer, as described in PCT publication Nos. WO/1999/042889 and WO/1999/044095, incorporated by reference herein.

Although, as previously stated, the present invention is not specifically restricted to the use of Liquid Crystal Display screens, for example, OLED, TOLED, Plasma or other display technologies may also be utilised for the first and/or second display layers. However, for ease of reference, embodiments of the present invention will be described using LCD displays. By way of a brief overview of LCDs, there are two main types of Liquid Crystal Displays used in computer monitors, passive matrix and active matrix.

Passive-matrix Liquid Crystal Displays use a simple grid to supply electrical charge to a particular pixel on the display. The grids made from a transparent conductive material (usually indium tin oxide), are formed using two glass layers called substrates, one provided with columns, the other with rows. The rows or columns are connected to integrated circuits that control when a charge is applied to a particular column or row. The liquid crystal material is sandwiched between the two glass substrates, and a polarizing film is added to the outer side of each substrate. To activate a particular pixel, the integrated circuit applies a charge to the relevant column of one substrate whilst grounding the corresponding row on the other substrate. The voltage applied to the intersection of the relevant row and column designating the pixel untwists the liquid crystals at that pixel.

However, the passive matrix system has significant drawbacks, notably slow response time and imprecise voltage control. Response time refers to the Liquid Crystal Displays ability to refresh the image displayed. Imprecise voltage control hinders the passive matrix's ability to influence a single pixel at a time. When voltage is applied to untwist one pixel, the pixels around it also partially untwist, which makes images appear fuzzy and lacking in contrast.

Active-matrix Liquid Crystal Displays depend on thin film transistors (TFT). Thin film transistors are tiny switching transistors and capacitors arranged in a matrix on a glass substrate. To address a particular pixel, the appropriate row is switched on, and then a charge is sent down the correct column. Since all of the other rows that the column intersects are turned off, only the capacitor at the designated pixel receives a charge. The capacitor is able to hold the charge until the next refresh cycle. Furthermore, if the amount of voltage supplied to the crystal is carefully controlled, it can be made to untwist only enough to allow some light through. By doing this in very exact, very small increments, Liquid Crystal Displays can create a greyscale. Most displays today offer 256 levels of brightness per pixel providing a 256-increment greyscale.

A Liquid Crystal Display that can show colours must have three subpixels with red, green and blue (RGB) colour filters to create each colour pixel. Through the careful control and variation of the voltage applied, the intensity of each subpixel can range over 256 shades. Combining the subpixels produces a possible palette of 16.8 million colours (256 shades of red x 256 shades of green x 256 shades of blue).

Liquid Crystal Displays employ several variations of liquid crystal technology, including super twisted nematics, dual scan twisted nematics, ferroelectric liquid crystal and surface stabilized ferroelectric liquid crystal. There are also emissive technologies such as Organic Light Emitting Diodes which are addressed in the same manner as Liquid Crystal Displays.

However, there are a number of practical considerations need to be addressed to produce a functional displays utilising multiple overlapping LCD screens, including the reduction or elimination of moire interference effects, coloured fringes, and crossed-polarisers, which are addressed in a number of ways including the use of diffusers, optical retarders and other optical materials and/or material finishes.

To aid understanding and for the sake of clarity, the MLD (1) and associated display screens (2, 3) are shown in simplified, schematic form in the drawings.

Figure 2 shows an exemplary general purpose computer system (100) which may be used to implement embodiments of the present invention. It will be appreciated that the computer system (100) shown in figure 2 is exemplary only and embodiments of the present invention may operate within a number of different systems including, but not limited to, embedded computer systems, portable and hand-held computer systems, mobile phones, or any computer system having the same general components or equivalents to the computer system shown in figure 2.

The computer system (100) has a processor (101) and at least one system memory (102) coupled by a bus (103) to the processor (101). The processor (101) may comprise a central processing unit (CPU) or other type of processor. Depending on the configuration and/or type of computer system environment, memory (102) may comprise volatile memory (e.g., RAM), non-volatile memory (e.g., ROM, flash memory, etc.), or some combination of the two. Additionally, memory (102) may be removable or non-removable. The computer system (100) may also have additional storage (e.g., removable storage (104), non-removable storage (105) or the like). Removable storage (104) and/or non-removable storage (105) may comprise volatile memory, non-volatile memory, or any combination thereof. Additionally, removable storage (104) and/or non-removable storage (105) may comprise CD-ROM, digital versatile disks (DVD), flash drives, solid state storage devices, or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to store information for access by the computer system (100).

As shown in figure 2, the computer system (100) can communicate with other systems, components, or devices via a communication interface (106). Communication interface (106) may embody computer readable instructions, data structures, program modules or other data in a modulated data signal (e.g., a carrier wave) or other transport mechanism. By way of example, and not limitation, communication interface (106) may couple to wired media (e.g., a wired network, direct-wired connection, etc.) and/or wireless media (e.g., a wireless network, a wireless connection utilizing acoustic, RF, infrared, or other wireless signalling, etc.).

Communication interface (106) also couples the computer system (100) to one or more input devices (107) (e.g., a keyboard, mouse, pen, voice input device, touch input device, etc.). Additionally, communication interface (100) may couple computer system platform (100) to one or more output devices (e.g., a speaker, printer, etc.).

As shown in Figure 2, optional graphics controller (108) may be provided and configured to receive first (7) and second (8) image data and respectively output a first and second image data signal to the front (2) and rear (3) screens for displaying the first (5) and second (6) images. The graphics controller (108) may perform graphics processing operations on the graphical image data (7, 8) stored in a frame buffer (109) or another memory (e.g. 102, 104 or 105) of computer system platform (100). Graphical data stored in frame buffer (109) may be accessed, processed, and/or modified by components (e.g., graphics controller (108), processor (101)) of computer system (100) and/or components of other systems/devices.

Accordingly, memory (102), removable storage (104), non-removable storage (105), frame buffer (109), or a combination thereof, may comprise instructions that when executed on the processor (101) implement a method of generating images on the multi-layered display (MLD) (1) as shown in figure 8.

- 5 As mentioned previously there is a potential problem in using overlapping LCD screens to simultaneously display images as any images on the rear screen overlapped by images on the front screen will be at least partially visible through the front image. As the overlapping images may often be unrelated and not coterminous, the interference between the overlapping images can make either or both images incoherent and difficult for the viewer to comprehend. In the prior art this overlapping problem was addressed by a method of producing a 'white' shadow or silhouette in either the front or rear screens in an overlapped/overlapping portion of one of the images to render that portion more transparent and therefore the other image portion (overlapping/overlapped) more visible. A viewer would thus only see the non-transparent image portions.
- 10
- 15 However, while this method addressed some of the problem of interference between overlapping images, the existence of the 'white' shadow introduced another problem in that a viewer was sometimes able to see the white shadow if not positioned so that their fixation axis passes through both the white shadow and the corresponding overlapping or overlapped portion. This generally occurred where the viewer's fixation axis was not close to perpendicular to the planes of the screens. Preferred embodiments of the present invention may address this problem as described below.
- 20

The computer system (100) in conjunction with the MLD (1) is configured to execute the *image generation algorithm* to display a target image (14) on the MLD (1) that is constructed from overlapping first (5) and second (6) images, as shown in figures 1b and 7. The first image (5) is displayed on the front screen (2) and therefore overlaps the second image (6) on the rear screen (3).

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The target image (14) includes a graphical object (9) displayed on the front LCD screen (2) and is provided in the form of an oval shape in the example of figure 1b and a star in the example of figure 7. It will be appreciated that the graphical object may be any part, whole or multiple of shapes, text, images and it will be appreciated that the oval and star are provided as examples only.

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The target image (14) also includes contextual elements (10) displayed on the rear LCD screen (3) which are provided in the form of an irregular quadrilateral in figure 1b and a

stripe pattern background in figure 7. Again it will be appreciated that the quadrilateral and stripe pattern are provided purely as examples for illustrative purposes only.

A silhouette (11) is also displayed on the rear screen (3) and is overlapped by the graphical object (9) with the peripheral boundaries being coterminous with the overlapping boundaries of the graphical object (9). The silhouette (11) is demarcated by the graphical object (9) on the front screen (2) and bounds a region of the rear screen (3) without any contextual elements (10).

In one embodiment the silhouette (11) displays a pattern, texture, intensity, colour or hue which is not visible or discernable through the graphical object (9) and in the embodiments shown in figures 3-8, the silhouette is generally 'white', i.e. the pixels of the rear screen (3) displaying the silhouette (11) are made substantially transparent.

Alternatively, the silhouette (11) may be a substantial copy of a graphical object (9) with the same colour and pattern etc.. However, as described above, displaying a silhouette overlapping/overlapped by a graphical object results in the corresponding composite target image having an alpha value equal to the silhouette and graphical object alpha values multiplied together. In order to compensate, for this problem, the silhouette (11) is displayed with an alpha value equal to the square root of the alpha value of the original graphical object and the graphical object is displayed with an alpha value equal to the original graphical object alpha divided by the silhouette alpha.

The silhouette (11) is also blurred to de-emphasise its boundary and reduce its detectability to a viewer.

As the silhouette (11) is overlapped by the graphical object (9) there will not be any interference with the graphical object (9) by the contextual elements (10) on the rear screen, as would be the case (see figure 4) in displaying the contextual elements (10) on the rear screen (3) behind the graphical object (9). However, as described above, a viewer in an 'off-centre' position may be able to see behind the graphical object (9) and see the silhouette (11) which would be distracting, unappealing and detract from the graphical object (9).

The graphical object (9) is thus displayed with a peripheral boundary region (12) that surrounds the graphical object (9) on the front screen (2) and is composed of the contextual elements (10) displayed on the rear screen (3) that are overlapped by the graphical object (9) adjacent the boundary region (12). A viewer off-centre will thus see the peripheral boundary region (12) and not the silhouette (11). As the peripheral boundary region (12) is composed of the contextual elements (10), it will appear to the

viewer that the peripheral boundary region (12) forms part of the contextual elements (10) on the rear screen (3) and thus the silhouette (11) will not be discernable by the viewer.

In order for the peripheral boundary region (12) of the graphical object (9) on the first screen (2) to merge unobtrusively with the rear screen (3), the contextual elements (10) and peripheral boundary region (12) on both screens (2, 3) are matched by creating the peripheral boundary region (12) with the contextual elements (10) overlapped by the peripheral boundary region (12).

However, in the embodiment shown in figures 3-7, the striped background contextual element (10) has a uniform appearance across the whole rear screen (3) and as such the contextual elements (10) used to provide the peripheral boundary region (12) need not be matched to a specific location.

The boundaries of the silhouette (11) and peripheral boundary region (12) are also manipulated by feathering. This feathering reduces an observer's awareness of the depth separation between the boundaries and instead presents the appearance of an uninterrupted continuum between the silhouette (11) and contextual elements (10) and between the boundary region (12) and contextual elements (10).

It will be appreciated that other ways of de-emphasising the boundaries of the silhouette (11) and/or peripheral boundary region (12) may be used and by way of example include: feathering, blending, defocusing, dithering, graduating, grading, sequencing, serializing, tapering the pattern, texture, intensity, colour, contrast, brightness, or hue of the boundaries.

Figure 9 shows a flowchart (200) of one embodiment of a method of generating images for display on the multi-layered display (1) and relates to the progression shown in figures 3-8 of images displayed on the MLD (1). The method is implemented by the computer system (100) which executes the *image generation algorithm* and generally involves the following steps:

201 Origin image data is accessed which forms an origin image (13) which includes a graphical object (9) and contextual elements (10). This origin image (13) is shown in figure 3.

202 The origin image data is processed to extract graphical object image data and contextual element image data respectively corresponding to the graphical object (9) and contextual elements (10). This graphical object image data and contextual element image data can be used to respectively display the graphical object (9)

and contextual elements (10) on front (2) and rear (3) screens, as shown in figure 4.

203 The graphical object image data is processed to generate silhouette data corresponding to the silhouette (11) displayed on the rear screen (3) (see figure 5).

5 The silhouette data is then processed to visually de-emphasize the boundary of the silhouette (11) with respect to the contextual elements (10). In the embodiment shown in figure 5, the silhouette boundary is manipulated by feathering with the contextual elements (10).

10 204 The contextual element image data is processed to generate boundary region data corresponding to the peripheral boundary region (12) for display on the front screen (2) (see figure 6). The boundary region data is also processed to visually de-emphasize the boundary of the peripheral boundary region with the graphical object (9) and silhouette (11). The entire stripe pattern of the peripheral boundary region is feathered to de-emphasize its boundary with the silhouette (11),
15 contextual elements (10) and graphical object (9).

205 First (7) and second (8) image data is then generated for display as the first (5)
and second (6) images (see figure 7) on the front (2) and rear (3) screens
respectively. The first image (5) includes the graphical object (9) and the
peripheral boundary region (12) while the second image (6) includes the
5 contextual elements (10) and silhouette (11).

206 The first (5) and second (6) images forming the target image (14) are then
respectively displayed on the front (2) and rear (3) screens as shown in figure 8
and figure 1b.

10 Figure 10 shows a flowchart (210) of another method according to an alternative
embodiment where the graphical object (9) and contextual elements (10) are already
provided. Therefore steps 201 and 202 are not required.

15 While reference herein has been made to the graphical object (9) and boundary region
(12) overlapping the contextual elements (10) and silhouette (11) it should be appreciated
that the present invention also includes the converse arrangement, i.e. the silhouette (11)
and contextual elements (10) being displayed on the front screen (2) overlapping the
graphical object (9) and boundary region (12) on the rear screen (3).

Aspects of the present invention have been described by way of example only and it
should be appreciated that modifications and additions may be made thereto without
departing from the scope thereof.

20 In the foregoing specification, embodiments of the invention have been described with
reference to numerous specific details that may vary from implementation to
implementation. Thus, the sole and exclusive indicator of what is, and is intended by the
applicant to be, the invention is the set of claims that issue from this application, in the
specific form in which such claims issue, including any subsequent correction. Hence, no
25 limitation, element, property, feature, advantage, or attribute that is not expressly recited
in a claim should limit the scope of such claim in any way. Accordingly, the specification
and drawings are to be regarded in an illustrative rather than a restrictive sense.

30 Aspects of the present invention have been described by way of example only and it
should be appreciated that modifications and additions may be made thereto without
departing from the scope thereof.

Claims

1. A computer-implemented method of generating images on a multi-layered display (MLD), the MLD including:
- 5 – a first display layer including a first plurality of pixels, the first display layer operable to display a first image using at least some of said pixels;
- a second display layer including a second plurality of pixels, the second display layer operable to display a second image using at least some of said second plurality of pixels, wherein one said display layer overlaps the other said display layer;
- 10 wherein said computer-implemented method includes execution of an image generation algorithm embodied in computer readable instructions stored in a computer-readable medium, said image generation algorithm executable to:
- display a target image on a MLD display, said target image including:
- 15 • a graphical object displayed on the first display layer, and
- contextual elements displayed on the second display layer,
- wherein a projection of the graphical object on the first display layer demarcates a silhouette on the second layer.
2. A method as claimed in claim 1, wherein target image is formed from an origin image having a graphical object and contextual elements.
- 20 3. A method as claimed in claim 2, wherein said silhouette is composed of said origin image graphical object.
4. A method as claimed in claim 3, wherein at least a portion of said silhouette is displayed with an alpha value proportional to the square root of the alpha value of a corresponding portion of said origin image graphical object.
- 25 5. A method as claimed in claim 4, wherein at least a portion of said silhouette is displayed with an alpha value equal to the square root of the alpha value of a corresponding portion of said origin image graphical object.
6. A method as claimed in any one of claims 2-5, wherein the alpha value of at least a portion of the graphical object displayed in the target image is proportional to the

alpha value of the corresponding origin image graphical object divided by the alpha value of a corresponding portion of the silhouette.

7. A method as claimed in any one of claims 2-6, wherein said silhouette is composed of a blurred copy of said origin image graphical object.
- 5 8. A method as claimed in any one of claims 1-7, wherein the silhouette peripheral boundary is manipulated to visually de-emphasize said boundary.
9. A method as claimed in claim 8, wherein said manipulation includes one or more of: feathering, blending, defocusing, dithering, graduating, grading, sequencing, serializing, tapering the pattern, texture, intensity, colour, contrast, brightness, or
10 hue of said boundary.
10. A method as claimed in any one of claims 1-9, wherein said silhouette bounds a region of the second display layer without any contextual elements.
11. A method as claimed in any one of claims 1-10, wherein the second display layer region bounded by said silhouette displays a pattern, texture, intensity, colour or
15 hue which is not visible or discernable through the graphical object on the first display layer.
12. A method as claimed in any one of claims 1-11, wherein said silhouette peripheral boundaries are coterminous with, or located within the overlapping boundaries of the graphical object on the first display layer.
- 20 13. A method as claimed in any one of claims 1-12, wherein said silhouette peripheral boundaries are concentric with the overlapping boundaries of the graphical object on the first display layer.
14. A method as claimed in any one of claims 1-13, wherein said graphical object is provided with a peripheral boundary region composed of contextual elements
25 displayed on the second display layer.
15. A method as claimed in claim 14, wherein said peripheral boundary region contextual elements substantially correspond to those contextual elements on the second display layer overlapped by and/or adjacent to the graphical object on the first display layer.
- 30 16. A method as claimed in any one of claims 14-15, wherein said image generation algorithm is executable to:

- retrieve target image data relating to said target image;
- process said target image data to:
 - generate graphical object data and contextual element image data respectively corresponding to said graphical object and said contextual elements for respective display on the first and second display layers;
 - process said graphical object image data and generate silhouette data corresponding to said silhouette;
 - process said contextual element image data to generate boundary region data corresponding to said boundary region

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17. A method as claimed in any one of claims 14-16 wherein said first and second images are respectively displayed on said first and second display layers, the first image overlapping the second image or vice versa and:

- said second image includes the silhouette and said contextual elements,
- said first image includes the graphical object and said boundary region.

15

18. A method as claimed in any one of claims 14-17, wherein the peripheral boundary region of the graphical object and/or the silhouette peripheral boundary are manipulated to visually de-emphasize said boundaries.

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19. A method as claimed in claim 18, wherein said manipulation includes one or more of: feathering, blending, defocusing, dithering, graduating, grading, sequencing, serializing, tapering the pattern, texture, intensity, colour, contrast, alpha values, RGB values, saturation, brightness, or hue of said boundaries.

20. A method as claimed in any one of claims 1-19, wherein said first and second images are respectively displayed on said first and second display layers, the first image overlapping the second image or vice versa and:

25

- said second image includes the silhouette and said contextual elements,
- said first image includes the graphical object.

21. An image displayed on a multi-layered display (MLD), the MLD including:

- a first display layer including a first plurality of pixels, the first display layer operable to display a first image using at least some of said pixels;

- a second display layer including a second plurality of pixels, the second display layer operable to display a second image using at least some of said second plurality of pixels, wherein one said display layer overlaps the other said display layer;

5 said image produced by the method as claimed in any one of claims 1-19.

22. A computer system configured to generate images for display on a multi-layered display (MLD), the MLD including:

- a first display layer including a first plurality of pixels, the first display layer operable to display a first image using at least some of said pixels;

10 – a second display layer including a second plurality of pixels, the second display layer operable to display a second image using at least some of said second plurality of pixels, wherein one said display layer overlaps the other said display layer;

15 wherein said computer system includes a system memory coupled by a bus to a processor, and wherein the system memory stores executable computer readable instructions embodying an *image generation algorithm* executable to generate target image data for display as a target image on a MLD display, said target image data including:

- 20 – first image data including data for display of a first image including a graphical object displayed on the first display layer, and
- second image data including data for display of a second image including contextual elements displayed on the second display layer,

 wherein a projection of the graphical object on the first display layer demarcates a silhouette on the second layer.

25 23. A computer system as claimed in claim 22, wherein target image is formed from an origin image having a graphical object and contextual elements.

24. A computer system as claimed in claim 23, wherein said silhouette is composed of said origin image graphical object.

30 25. A computer system as claimed in claim 24, wherein at least a portion of said silhouette is displayed with an alpha value proportional to the square root of the alpha value of a corresponding portion of said origin image graphical object.

26. A computer system as claimed in claim 25, wherein at least a portion of said silhouette is displayed with an alpha value equal to the square root of the alpha value of a corresponding portion of said origin image graphical object.
- 5 27. A computer system as claimed in any one of claims 22-26, wherein the alpha value of at least a portion of the graphical object displayed in the target image is proportional to the alpha value of the corresponding origin image graphical object divided by the alpha value of a corresponding portion of the silhouette.
28. A computer system as claimed in any one of claims 22-27, wherein said silhouette is composed of a blurred copy of said origin image graphical object.
- 10 29. A computer system as claimed in any one of claims 22-28, wherein the silhouette peripheral boundary is manipulated to visually de-emphasize said boundary.
30. A computer system as claimed in claim 29, wherein said manipulation includes one or more of: feathering, blending, defocusing, dithering, graduating, grading, sequencing, serializing, tapering the pattern, texture, intensity, colour, contrast, 15 brightness, or hue of said boundary.
31. An image generation algorithm embodied in computer readable instructions and executable by a computer system to generate target image data corresponding to a target image for display on a multi-layered display (MLD), said image generation algorithm executable to perform a method as claimed in any one of claims 1-20.
- 20 32. An image generation algorithm as claimed in claim 31, wherein said image generation algorithm is executable to generate said target image data by processing origin image data corresponding to an origin image having a said graphical object and contextual elements.
- 25 33. An image generation algorithm as claimed in claim 32, wherein said origin image data is processed to extract graphical object image data and contextual element image data respectively corresponding to said graphical object and said contextual elements. A computer-implemented method of generating images on a multi-layered display (MLD), the MLD including:
- 30 – a first display layer including a first plurality of pixels, the first display layer operable to display a first image using at least some of said pixels;
- a second display layer including a second plurality of pixels, the second display layer operable to display a second image using at least some of said second

plurality of pixels, wherein one said display layer overlaps the other said display layer;

wherein said computer-implemented method includes execution of an image generation algorithm embodied in computer readable instructions stored in a computer-readable medium, said image generation algorithm executable to:

- display a target image on a MLD display, said target image including:
 - a graphical object displayed on the first display layer, and
 - contextual elements displayed on the second display layer,

wherein said graphical object is provided with a peripheral boundary region composed of contextual elements displayed on the second display layer.

34. A computer system configured to generate images for display on a multi-layered display (MLD), the MLD including:

- a first display layer including a first plurality of pixels, the first display layer operable to display a first image using at least some of said pixels;
- a second display layer including a second plurality of pixels, the second display layer operable to display a second image using at least some of said second plurality of pixels, wherein one said display layer overlaps the other said display layer;

wherein said computer system includes a system memory coupled by a bus to a processor, and wherein the system memory stores executable computer readable instructions embodying an *image generation algorithm* executable to generate target image data for display as a target image on a MLD display, said target image data including:

- first image data including data for display of a first image including a graphical object displayed on the first display layer, and
- second image data including data for display of a second image including contextual elements displayed on the second display layer,

wherein said first image data includes data for display of a peripheral boundary region of said graphical object composed of contextual elements displayed on the second display layer.

Figure 1

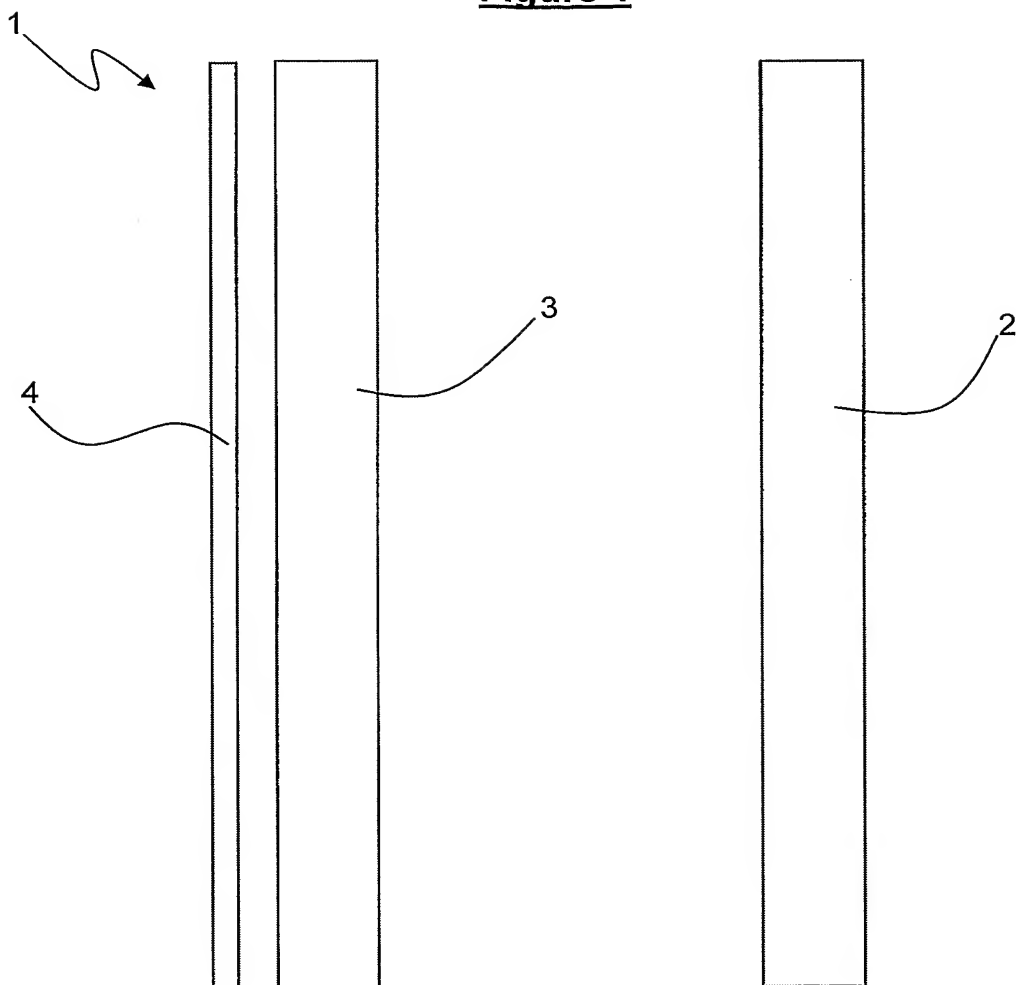


Fig 1a

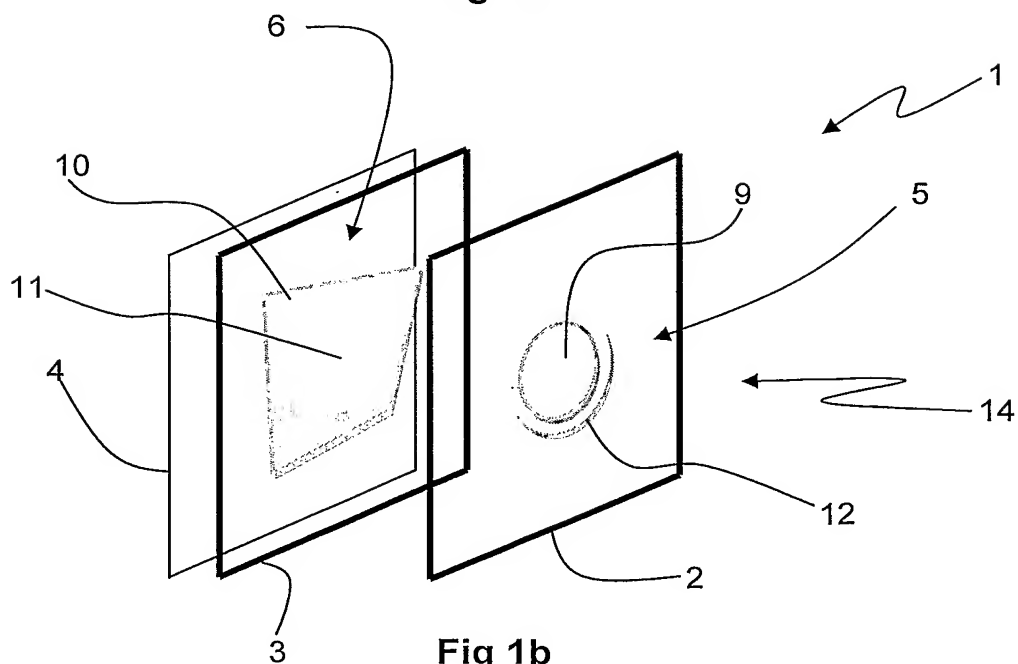


Fig 1b

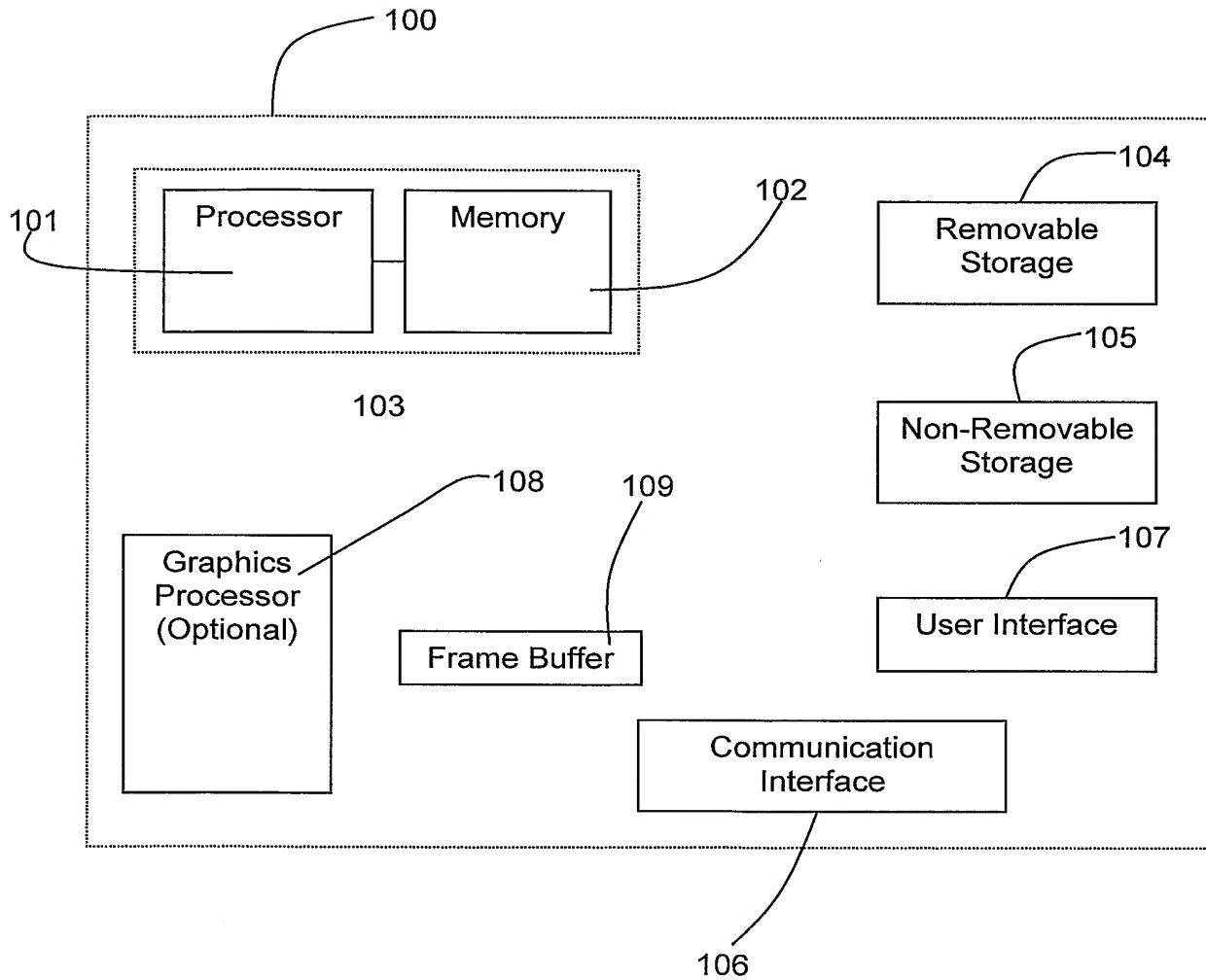
Figure 2

Figure 3

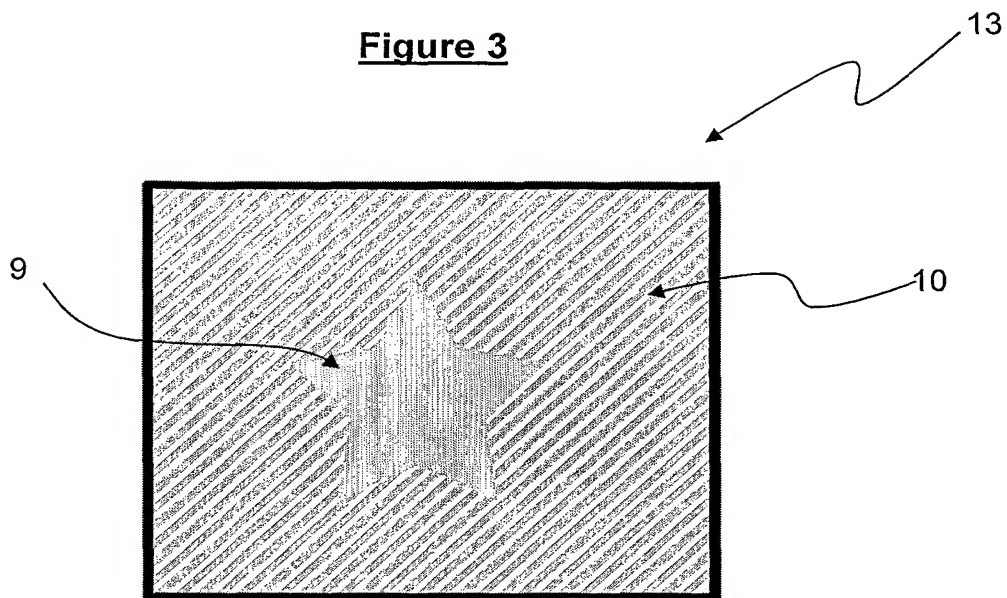


Figure 4

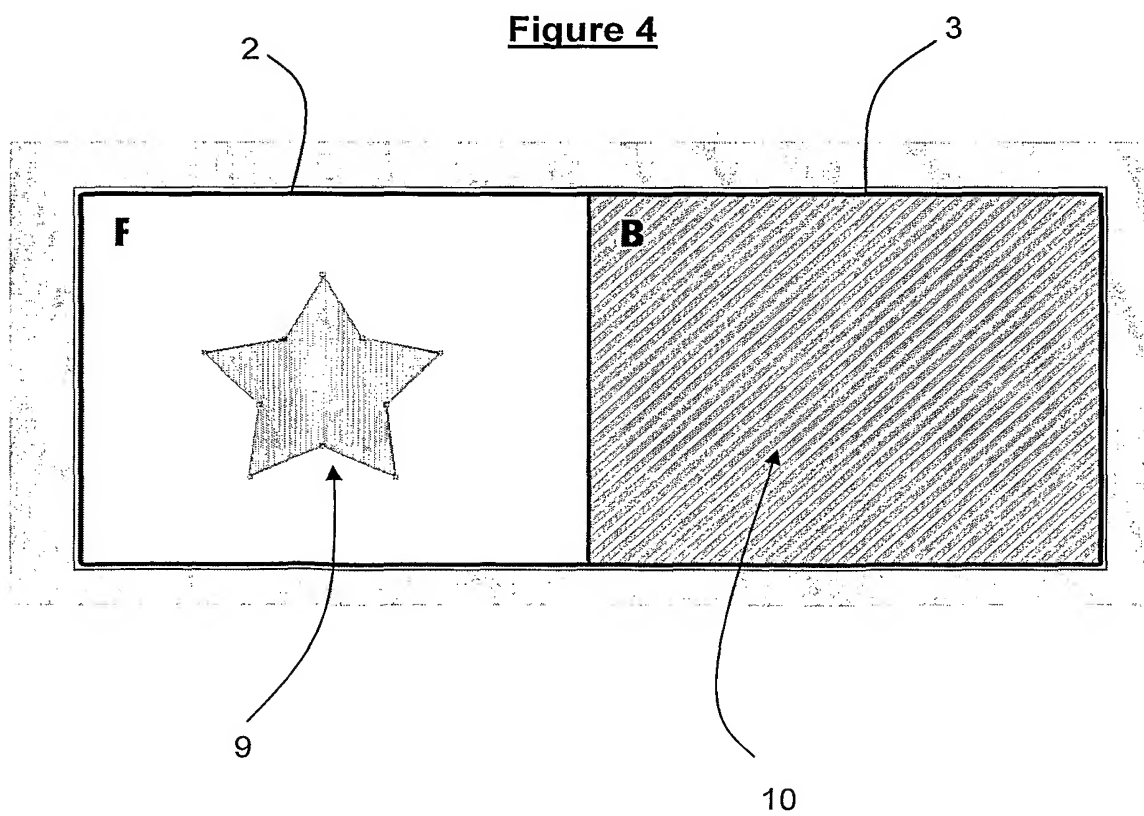


Figure 5

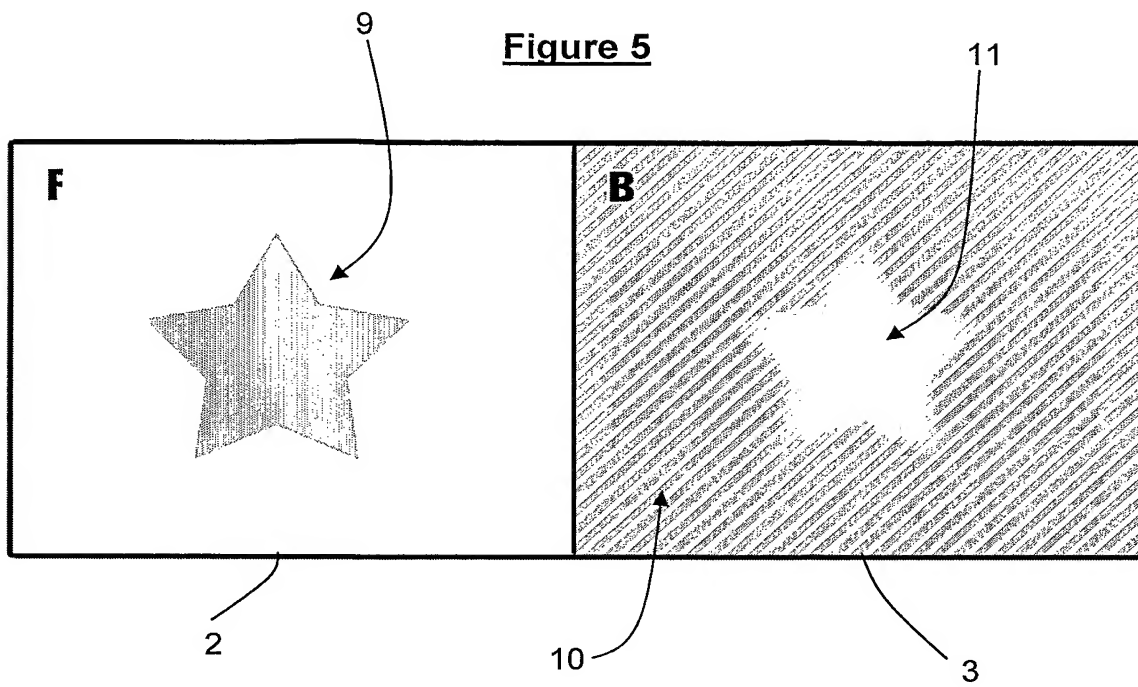


Figure 6

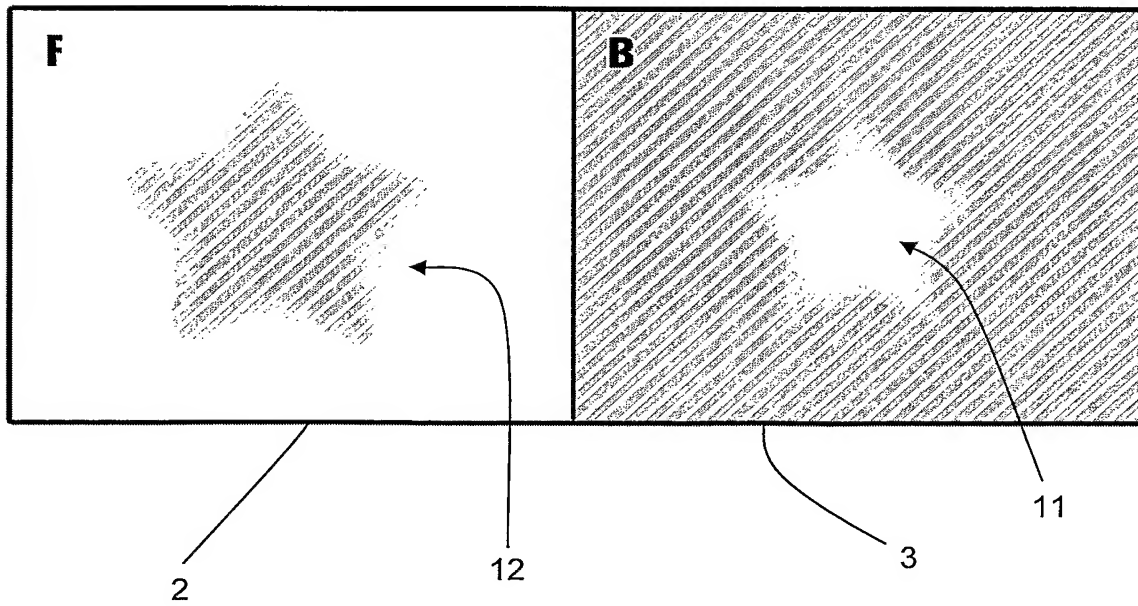


Figure 7

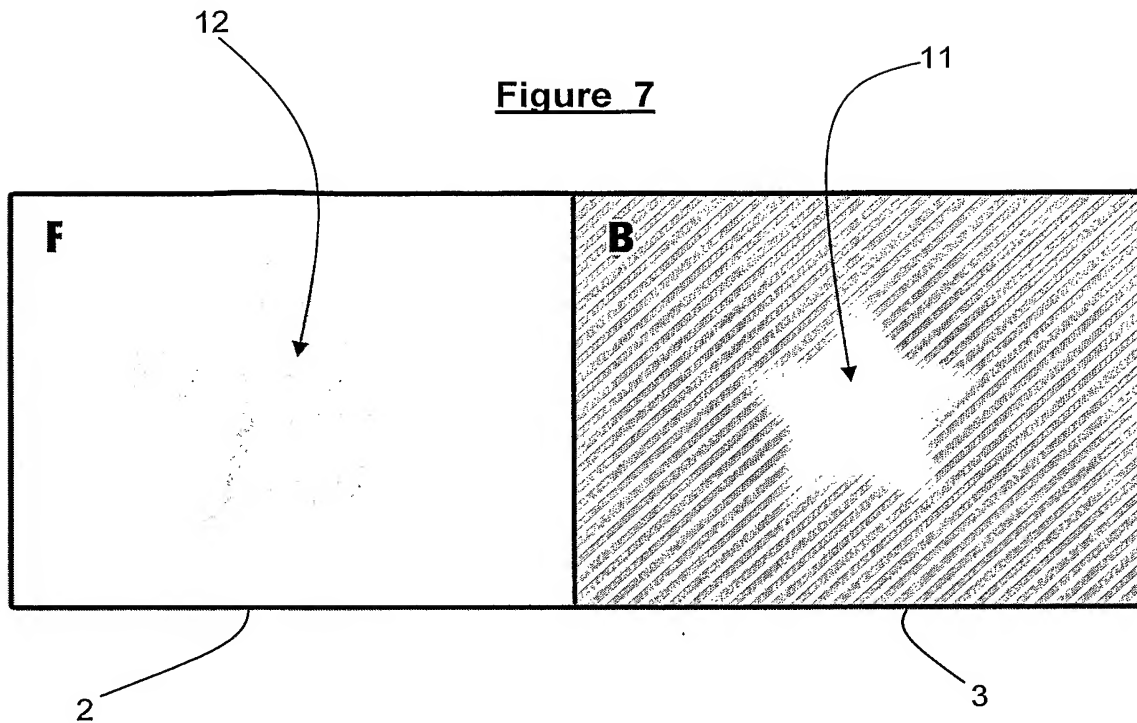


Figure 8

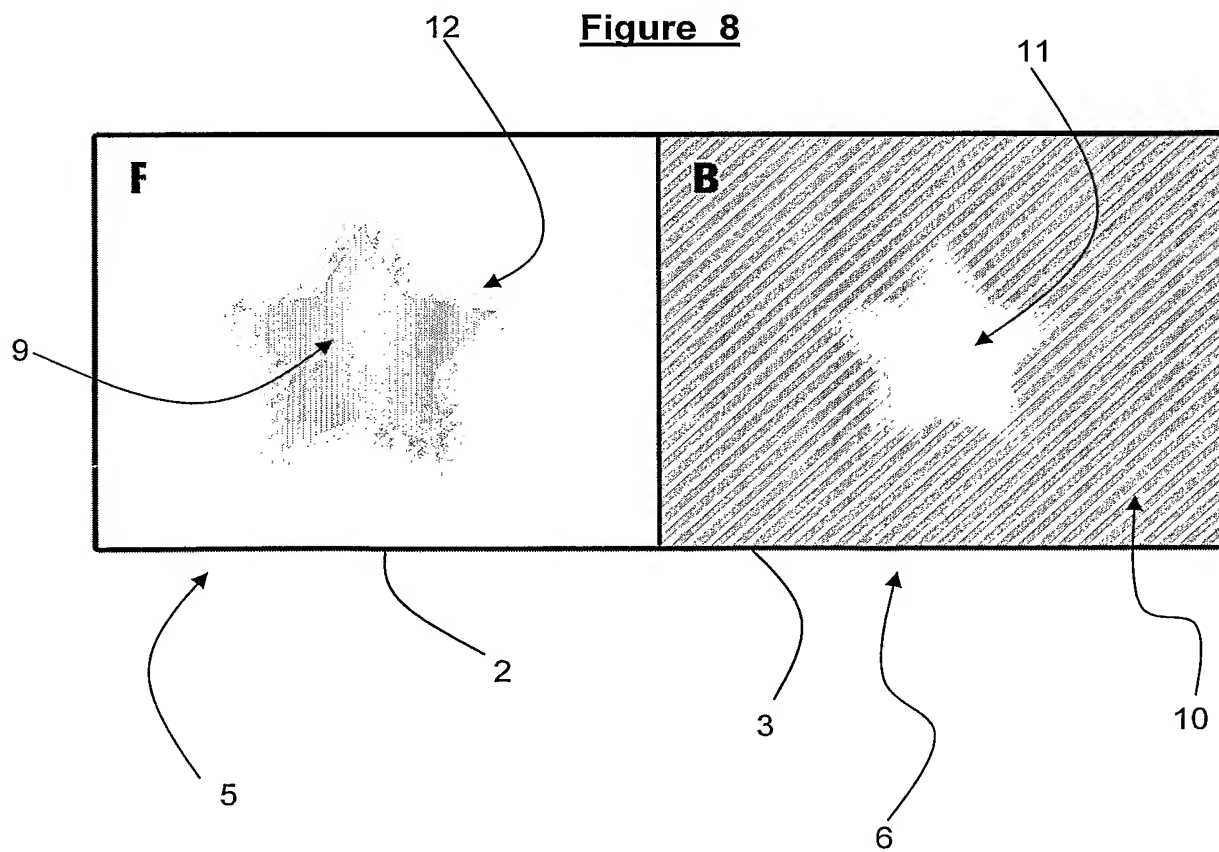


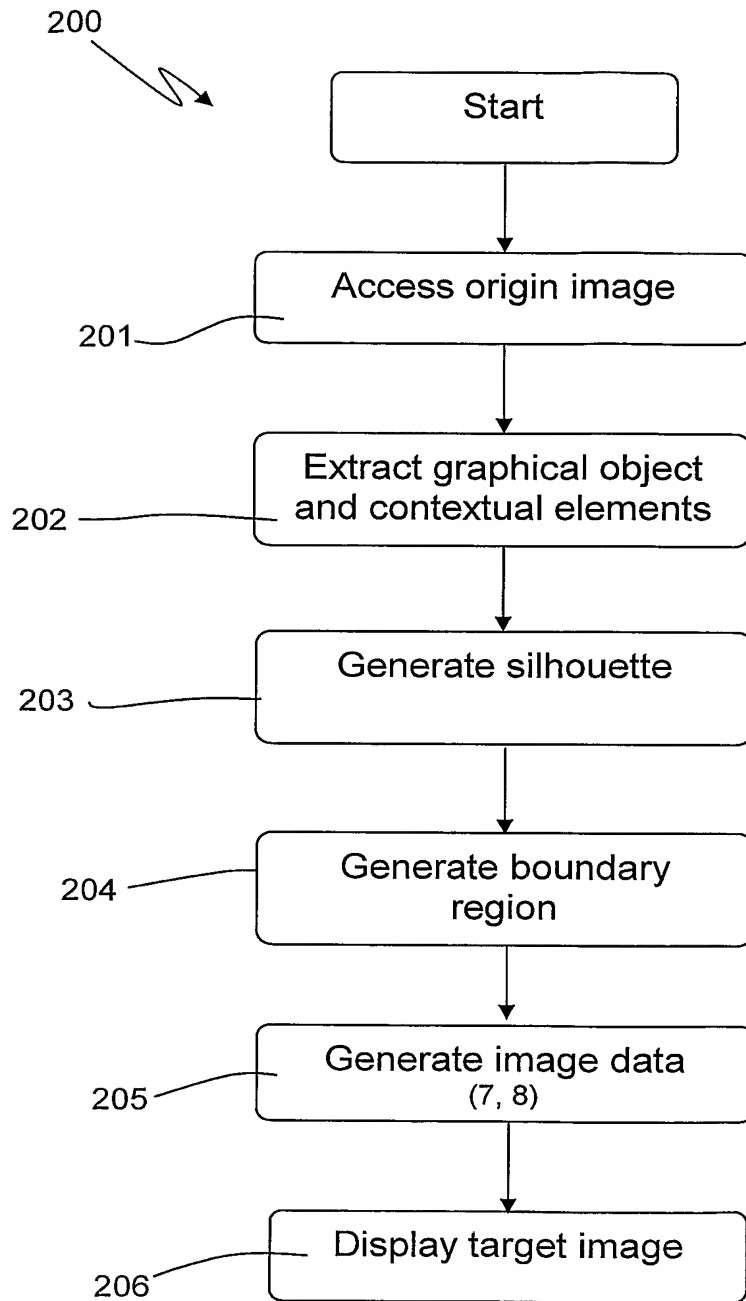
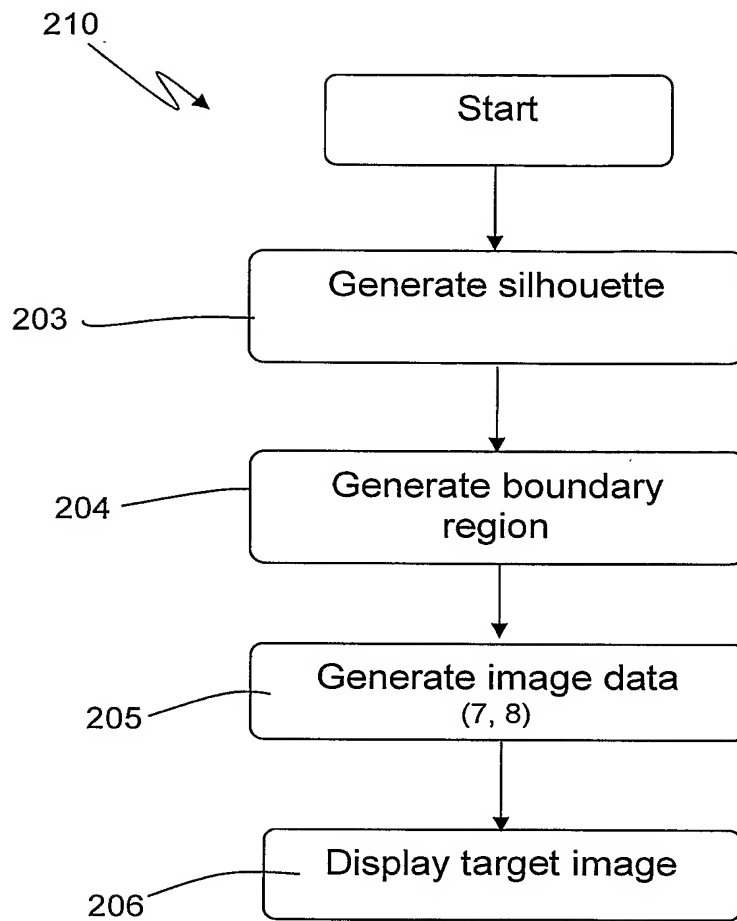
Figure 9

Figure 10

INTERNATIONAL SEARCH REPORT

 International application No.
PCT/IB2009/006645
A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

G02F 1/1347 (2006.01)**G06T 15/00** (2006.01)**G02F 1/13** (2006.01)**G09G 5/00** (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, Epodoc, Google Patent Search, Es@cenet, Patent Lens: keywords (multi-layered display, silhouette) and similar terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages. | Relevant to claim No. |
|-----------|---|-----------------------|
| X | WO 2007/040413 A1 (PURE DEPTH LIMITED) 12 April 2007 See page 1 lines 5-10; page 2 line 18-page 3 line 14; page 4 lines 12-13; page 6 lines 18-20; page 7 line 10-11; page 8 lines 18-20; Fig. 1 | 1-13, 20-34 |
| Y | page 2 lines 20-22; page 3 lines 1-8; page 4 lines 10-13; page 6 line 18-20 | 14-19 |
| X | US 6906762 B1 (WITEHIRA et al.) 14 June 2005 See abstract; column 2 lines 27-35; column 5 lines 31-40; claims 1, 16 | 1, 20-22, 34 |
| X | WO 1999/044095 (WITEHIRA et al.) 2 September 1999 See page 11 line 13-19; page 12 lines 14-25, page 13 lines 17-20 | 1, 20-22, 34 |

☒ Further documents are listed in the continuation of Box C☒ See patent family annex

| | |
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 Date of the actual completion of the international search
 11 January 2010

 Date of mailing of the international search report
19 JAN 2010

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INTERNATIONAL SEARCH REPORT

International application No.

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| C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT | | |
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| A | US 7193631 B2 (MUELLER et al.) 20 March 2007 Whole document | 1-34 |
| A | US6369830 B1 (BRUNNER et al.) 9 April 2002 Whole document | 1-34 |
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/IB2009/006645

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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| Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001. | | | | | | | |
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